ON LORD ROSSE'S TELESCOPE.

Dr. Robinson, when giving, in November, 1840, to the Academy, an account of the three-feet telescope constructed by the Earl of Rosse, had announced to them the intention of that nobleman to attempt an instrument of double aperture and focal length. The attempt had succeeded even beyond expectation, and he hoped that a brief notice of its progress and results would not be uninteresting; more especially as he felt that the approbation with which they had received his former communication, and the importance which they attached to Lord Rosse's discoveries, had not been the least powerful cause of the triumph which their countryman has now achieved.

The speculum was cast on the 13th of April, 1842, according to the principles which had been so successfully applied to the smaller mirrors; but with several changes of the details, made necessary by the gigantic scale of the work.

It is well known to all who have experimented on specula, that the alloy must be formed in the first instance, and remelted for casting at a much lower heat: otherwise the mirror is full of pores. The fusion must, in both cases, be effected in covered crucibles, to preserve the definite proportions of the alloy, which would be *lowered* by oxidation of its tin if exposed to the draught of the furnace. It is also necessary that the speculum be of uniform composition and superficial density; and as it is impossible to fuse the requisite quantity of metal for one of six feet in a single vessel, the different portions must flow into the mould under circumstances as nearly as possible identical. Much thought and many experiments must have been expended before these conditions were so completely fulfilled. The crucibles are, of course, cast iron; no earthen one being able to bear the pressure of such a mass of fluid metal at so high a temperature. They are thirty inches internal depth, and twenty-four diameter, weighing

about half a ton each, and manufactured with the precautions pointed out by Lord Rosse (Phil. Trans. 1840). Notwithstanding their great strength, they yield so much that it is obviously hazardous either to use them frequently or to increase their dimensions. Three were employed at once, each containing about one and a half tons of the alloy: they were placed in furnaces whose mouths were level with the ground, eight feet deep and four in diameter, disposed round a large stack or chimney, into which their flues vent. The fuel is turf, peculiarly fitted for this work, as giving a much more manageable heat than coke; about 2200 cubic feet of it are consumed in a casting. The furnaces were filled with fuel, and ignited at the top, on the preceding evening, that the crucibles might be gradually heated; and in about ten hours they were ready to receive the metal. This was unintentionally made of a lower standard than that of the three feet, in consequence of the atomic number for tin being taken as given in Turner's Chemistry, 57.9 instead of 58.9, causing a deficiency of about half per cent, too trifling to impair materially its reflective power, though it will certainly make it more liable to tarnish. That its uniformity might be insured, each ingot of it was broken into three pieces, as nearly equal as possible, and stored in three casks, each of which contributed equally to form the successive charges of the crucibles in an order regularly varying. They were charged at intervals of two hours, and the whole was fused in twelve: they were then withdrawn from the furnaces by a powerful crane, and transported to the iron cradles of pouring frames, arranged 90° asunder round the mould.

The essential part of the mould is its base, composed of hoop iron six inches broad, packed on edge in a strong frame seven feet diameter, and supported by strong transverse bars below. The upper surface was turned to a convex segment of a sphere, 108 feet radius, on the polishing machine, over which a self-acting slide rest was fixed, whose frame was of

the same curvature. This process required several weeks, and it was then ground smooth by a frame filled with concave blocks of sandstone. The bed of hoops so prepared being set exactly level, and heated sufficiently to blue its surface (for the purpose of burning out the tallow with which its interstices are filled, when not in use, to protect it from oxidation), the wooden pattern of the speculum was placed on it, and founders' sand rammed round it to its top. The mould thus formed was about a foot deep, the thickness of the speculum, $5\frac{1}{2}$ inches in this instance, being determined by the quantity of metal melted. By this arrangement, as Dr. Robinson formerly explained to the Academy, the fluid metal which comes in contact with the hoops is *chilled* at once into a dense sheet about half an inch thick; the air which might be entangled with it in pouring, escaping through their interstices. The circumference sets much more slowly in consequence of the inferior conducting power of the sand ; and the upper surface, which is only in contact with air, remains so long fluid, that the greatest part of the shrinkage occurs there ; its tendency to crack the cast is prevented, and the coarse structure which it produces is confined to a place where it is unimportant.

On this occasion, besides the engrossing importance of the operation, its singular and sublime beauty can never be forgotten by those who were so fortunate as to be present. Above, the sky, crowded with stars and illuminated by a most brilliant moon, seemed to look down auspiciously on their work. Below, the furnaces poured out huge columns of nearly monochromatic yellow flame, and the ignited crucibles, during their passage through the air were fountains of red light, producing on the towers of the castle and the foliage of the trees, such accidents of colour and shade as might almost transport fancy to the planets of a contrasted double star. Nor was the perfect order and arrangement of every thing less striking : each possible contingency had been foreseen,

each detail carefully rehearsed; and the workmen executed their orders with a silent and unerring obedience worthy of the calm and provident self-possession in which they were given.

It has been found that a good criterion of the time for pouring the alloy into the mould is afforded by stirring it with a pole of dry wood. This, as long as the temperature is above a certain point, reduces the film of oxide which covers its surface; and it becomes clean and bright, though a new film forms immediately. At length as it cools this reduction no longer occurs; and at a signal the three crucibles are emptied into the mould by means of levers connected with the pivots of their cradles. Though familiar with heavy castings, Dr. Robinson had never seen any thing so magnificent as the burning lake that was then produced; and for many minutes it rolled in heavy waves like those of quicksilver, which broke in a surf of fire on the sides of the mould, effecting the most perfect mixture of the metal. At last it became solid, and was examined as it cooled, till it barely yielded to pressure with an iron rod at its centre, which is the indication that it may be removed to the annealing furnace.

This furnace extends along the fourth side of the mould: it is a low square chamber lined with firebrick, with sides about thirty inches thick, strongly hooped, and covered by an arch, from the centre of which rises a flue. Its floor is convex, of the same curvature as the speculum, and is heated from beneath by nine arches, which communicate with lateral flues. It opens towards the mould by a low arch a little wider than the speculum; but behind has merely an aperture to admit an iron bar. For some weeks the chamber and arches had been kept full of burning turf, so that the whole interior was of a full red heat. The speculum, also red hot (at which temperature, it is to be remarked, the alloy has nothing of that brittleness which characterizes it when cold, but is as tough as malleable iron), was cleared from the sand, and encircled by

a strong ring attached to the bar above mentioned. By connecting this bar with a powerful capstan, it was drawn from the bed of hoops, along strong beams covered with iron, to its place in the centre of the annealing furnace. The ring was then removed, and the rest of the chamber filled up with charcoal; the arches with fuel; all the flues and apertures were closed carefully with masonry, and it was left to cool gradually for sixteen weeks, during the first three of which the exterior of the building was sensibly warm.

In the course of this year considerable progress was made with various parts of the mounting; and when Dr. Robinson visited it in February, 1843, he found that the speculum had been ground (on a machine similar to the old one, but of strength proportioned to its work); that the foundations of the piers were laid, the tube was in preparation, and the massive frame-work and levers by which the speculum is supported in the tube, were cast. This elegant contrivance requires some explanation. Suppose the back of the mirror divided by two concentric circles into three portions, of which the central circle is cut by radial lines into six sectors, the middle zone into nine segments, and the exterior into twelve, and that all of these are equal. If each of these be supported by an equal force applied at its centre of gravity, the speculum is obviously in the most favourable condition as to flexure. The frame mentioned above is rectangular with a cross-piece cast in one, and weighs one ton and a half: it bears three strong triangles, also of cast iron, supported at their centres of gravity on hemispherical bearings. Each angle of each of these bears a similar triangle, the angles of which give the twenty-seven points of equilibrated bearing for the speculum. They do not, however, press directly, but carry platforms of cast iron of the shape of the areas which they are to bear, and made exceedingly stiff by flanches at their edges, and by edge-bars crossing them diagonally. A layer of felt is over these; strong uprights from the frame of a similar character prevent any lateral

shifting ; and the operation of the arrangement is found to be perfect at all altitudes.

The construction of the tubes, the piers, the mechanism of the counterpoises, occupied the remainder of this year and the beginning of 1844. In August, a partial polish was given to the mirror in order to verify its focal length (which was found exactly fifty-four feet) ; and the observing galleries and the apparatus for controlling the instrument in right ascension were proceeded with. All these gigantic constructions (of whose prodigious mass some idea may be formed from the fact that they contain, along with their other materials, more than one hundred and fifty tons of iron castings), have been executed in Lord Rosse's workshops, by persons taken from the surrounding peasantry, who, under his teaching and training, have become accomplished workmen, combining with high skill and intelligence the yet more important requisites of steady habits and good conduct. It may also be mentioned that (such was the clear and definite arrangement of the whole in its inventor's mind) nothing failed from first to last ; and it was not necessary for him in any instance to retrace his steps.

At the beginning of February, 1845, the work being sufficiently advanced to permit the use of the instrument without personal danger, Dr. R. and his friend Sir James South were invited to enjoy the trial of it. Its appearance is certainly peculiar, and presents a striking contrast to the more complicated framing of the three-feet telescope which is placed beside it. At first sight, one wonders how it is to be moved, for nothing attracts notice except the massive piers and the tube; but a nearer approach shews that it is the perfection of mechanical engineering. To have mounted it on the plan of the three-feet would have been impracticable as well as useless. The speculum with its supports is seven times the weight of that in Herschel's four-feet, and both on this account, and the well-known principle that similar machines are weaker in proportion to their bulk, such a stand must have been so heavy

as to present great obstacles to its motion. The vast surface exposed to the action of wind must have made it unsteady; and its durability could not be great. Lord Rosse, therefore, determined to confine the range of observation to the vicinity of the meridian. There the stars are at their greatest altitudes, and atmospheric influences affect them least; their places can be determined with most accuracy, and an equatorial movement, so essential to micrometer measures, can be easily obtained. With such optical power there will never be a scarcity of objects for examination; and the restriction will only be felt in the case of planetary bodies. The base of the actual mounting is a very massive joint of cast iron; its lower axis permitting motion in the meridian plane, its upper in a direction perpendicular to that circle. On this is firmly bolted a cubical wooden chamber, about eight feet wide, in which the speculum is placed, one of its sides opening for the purpose. This again carries the tube, which when vertical and viewed from the interior of the chamber, is more like one of the old round towers than any more ordinary object of comparison. It is fifty feet long, eight feet in diameter in the middle, but tapering to seven at the extremities: it is made of deal staves an inch thick, hooped with strong iron clamp-rings, and secured from collapse by iron diaphragms; and carrying at its upper extremity the apparatus of the Newtonian small mirror, which, from its great weight and bulk requires to be counterpoised. The telescope is moved in declination by a strong chain cable attached to its top and passing over a pulley fixed at a proper height to the north, down to a windlass on the ground which is wrought by two workmen. East and west, near the top of the piers, large iron pulleys are fixed, having free movement in azimuth, so that their planes may always be in those of the traction: chains suspending the counterpoise weights pass over these to the sides of the tube. The weights, however, are constrained to descend in quadrants of circles by chain guys attached to the frame which bears the declination pulley. It is easily seen

that their action is a maximum when the tube is level, and nothing when it is vertical; but between these positions it decreases more slowly than the downward tendency of the tube. To correct this, the tube is connected with loaded levers (placed to its south), by chains of such lengths that one of them is not raised till it is at 40° altitude, and the other at 80°; the latter being necessary for the return of it after it has passed the zenith. The slow motion in declination was not yet applied, but the ordinary one was quite convenient, except for the difficulty of giving orders to the men, who were sometimes seventy or eighty yards from the observer. A two-feet circle, with a fine level and a pair of verniers, will also be attached to the tube to give the declination; its place was then supplied by a small protractor, five inches diameter, over which was a strong screen to protect the assistant who attended it from any such casualty as the fall of an eye-piece.

The eastern pier bears what may be called the meridian of the instrument: it is a strong semicircle of cast iron, about eighty-five feet diameter, and composed of several pieces accurately planed. Each of these is bolted to the pier and separately adjustable to a meridian line formed by straining a fine wire over notches in two cast iron chairs firmly secured at the north and south of the masonry. Sir James South took charge of this delicate operation, and performed it with such precision that when a transit instrument was adjusted by this line, it gave the passage of Polaris *to a small fraction of a second.* The telescope is compelled to move in the meridian, being connected with this circle by a strong bar provided with friction rollers, that it may traverse it easily; and thus it can be used as a transit instrument with considerable precision. But this bar is racked, and attached to the tube by wheelwork, so that a handle near the eye-piece enables the observer to move it on either side of the meridian, and thus examine it before its passage, or follow its motion. The movement is surprisingly easy; and a rough graduation on the bar supplies at present

the place of an hour circle for finding objects, for which it is quite sufficient, except that the strong light required to set it disturbs the repose of the eye. The elder Herschel has not in the least exaggerated the importance of this when faint objects, especially nebulæ, are to be examined; and a better contrivance is to be applied. The rack being perpendicular to the meridian, gives a motion not strictly equatorial, but easily made so: had the declination pulley been in a parallel to the earth's axis, passing through the great joint, and had this latter been itself equatorial, this would have been the case; but the deviation is easily corrected by the addition of a second pulley altering the direction of the chain. Its range is half an hour on each side of the meridian for a star at the equator; and Lord Rosse intends to effect it by clock-work, as is now generally the case in large equatorials; though the problem is much more difficult than in those instruments.

The western pier supports the stairs and galleries destined to the observers. Up to 42° of altitude is commanded by the first of them: a strong and light prismatic framing slides between two ladders attached to the southern faces of the piers: it is counterpoised and is raised to any required position by a windlass; its upper plane affords support for a railway on which the observing gallery moves about twenty-four feet east and west, two of its wheels being turned by a winch near the observer. Three other galleries in succession reach to 5° below the pole; these are each carried by two beams which run between pairs of grooved wheels, and are drawn forward, when they are turned, by a mechanism of singular elegance. These are able to hold twelve people, but one man can easily work them; and though it is rather startling to a person who finds himself suspended over a chasm sixty feet deep, without more than a speculative acquaintance with the properties of trussed beams, all is perfectly safe. Every bearing part has been *proved* to ten times its utmost probable load, and the doors of the galleries open inward, and are kept close by springs. From this point too is

obtained the most distinct perception of the telescope's prodigious bulk, which at a greater distance is not so striking, for want of a standard of comparison; yet, notwithstanding the hugeness of the masses to be moved, so effective are all the arrangements that Sir James South found it was possible to uncover the mirrors and find a given star in less than eight minutes.

Unfortunately the whole month of February was of the worst astronomical character; and though the great speculum had only the imperfect polish already noted, it was kept in the tube as long as there were any hopes of seeing the great nebula of Orion. That, however, was always clouded while within its range. A few clear minutes on the 13th allowed them to see some stars and clusters; but the only circumstances worth mentioning were, that it shewed the stars of Castor far apart *without an eye-glass*,* and that the stars of the cluster 67 Messier, which Sir J. Herschel describes as being from the eleventh to the twelfth magnitude, were many of them as bright as those of the first appear in a three and a-half feet achromatic.

At length, when all hopes of Orion were lost in the twilight, the mirror was removed from the telescope, and polished on March 3rd. Its frame is supported in the cubic chamber of the tube by three strong screws which give the adjustment of its optic axis. By unscrewing these, when the tube is vertical, four wheels with which the frame is furnished come to bear on a railroad fixed at the bottom of the chamber and communicating over a bridge (laid from its door when necessary) with another railway laid on an inclined plane of about sixty feet. It is drawn up this by the declination windlass, and at its top runs on a strong truck by means of which it is drawn a quarter of a mile, on a common road, to the laboratory.

The polishing machine differs in nothing but size from that

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* Only twenty-two inches of the mirror could act in this case.

described by Lord Rosse in the Philosophical Transactions. It makes the speculum revolve once for twenty-four and a-half strokes, and the eccentric once for eighteen. From seven to eight strokes of twenty-four inches are made in the minute, and the lateral movement of the speculum by the eccentric is fourteen inches.* A screw whose nut runs on a railroad above the machine lifts the speculum, with its frame and levers, from the truck, and deposits it on the revolving platform, where it is levelled, centred, and secured. The same apparatus serves to move the polisher during its preparation and to apply it to the speculum, so that it is even more manageable than that of the three-feet was. It was cast with the transverse grooves; the circular were cut in the lathe. The time required for polishing is about six hours; and Lord Rosse has found that this period cannot be exceeded without injury to the figure, in consequence of the soft pitch being squeezed out, and the harder and unyielding material coming into contact with the iron of the polisher: unfortunately, this occurred to some extent in the present instance. The ammoniacal solution of soap used towards the close of the process, happened to be made with ammonia prepared from gas liquor and containing some sub-

* These are the proportions which Lord Rosse prefers; but it must be kept in mind that they change with circumstances. *Probably* they will not answer for those specula which have an aperture larger than one-ninth of their focal length, and *certainly* not for those which are perforated in the middle. Dr. Robinson has made many experiments on one of the latter, fifteen inches aperture and nine feet focus, with a machine nearly the same as Lord Rosse's; and he finds that the nature of the polishing depends on the figure given in grinding. If the eccentric be regulated so as to make this hyperbolic, its action must be lessened in polishing so as to shorten the focus. In this way it is possible to obtain very good results. He, however, prefers the opposite course pointed out by Lord Rosse; grinding to an elliptic figure, he polishes with a very long primary stroke, and small action of the eccentric. A speculum thus polished shews ε Arietis well separated and defined with 940, and with 465 the fifth star in the trapezium of Orion's nebula is visible even when the acting surface is reduced to seventy-two circular inches.

stance which acted on the mirror and produced a dulness that was not removed till after three hours' additional work. Lord Rosse warned them that the figure must be imperfect, and wished to repolish; but they overruled this proposal, and it was replaced in the tube next day.

On examining it by diaphragm and discs, it was found that, as he anticipated, the edge was not quite perfect. All its zones showed ξ Ursæ Majoris very well with 560; but the exterior six inches manifested, when the star was thrown out of focus, that though of the same focal length, this portion was irregular. Few other double stars were observed, as most of the lucid interval from the 4th to the 13th of March was devoted to nebulæ, and after that it again became cloudy; but enough were seen to satisfy them that the instrument possessed a very high defining power. This, indeed, was evident from the admirable exhibition of Regulus, seen on March 5th, neat and round, without appendages or flare. Gamma Leonis, ξ Virginis, 2 Comæ, and Gamma Virginis, were also well shewn with powers of 400 to 800 on an unfavourable night; and the companions of ν Ursæ, and 245 of Struvé's second Catalogue, which appear in the Slough and Pulkova telescopes as of the eleventh and tenth magnitudes, seem in this large stars.

Of planetary bodies, none were visible except D'Arrest's Comet and the Moon. The former, when viewed March 10th, presented nothing remarkable: the brighter portion, towards the centre, shewed no abrupt change of light which might indicate a solid nucleus; there was no resolvable appearance in the Coma, and the very minute stars with which that part of the sky was dotted, were visible almost to its very centre. Only one view of the moon was obtained, March 20th, and it was shared with them by several visitors, who, when once in possession of the telescope, were by no means disposed to make way for the astronomers. The fascination of the sight is, indeed, such, that one can scarcely withdraw the eye:

Dr. Robinson, therefore, and his friend, had but little time for observation. He was, however, much interested by the vicinity of the craters named Hansteen and Mairan, in the map of Beer and Mædler, where, besides the crowd of hills described by them, these are an infinity of others not visible even in the three-feet, but looking in this with 560 like grains of sand. Are these fragments ejected from the crater? If so, and if they occur round others, it would explain what had always presented to him a great difficulty. The lunar craters differ widely from those of earth; and most in this, that their depression below the general surface is enormously greater than the elevation of their walls above it, while the area of the hollow is far greater than that of the latter. What, then, became of the materials which had once filled it? He had formerly supposed that they were in a fluid or gaseous state when ejected; but the fact just mentioned seems to give the true solution, and appears to account for them when combined with the consideration of the feeble gravity on the moon, which would permit the exploded fragments to be scattered over a far larger space than with us. Another beautiful object was the river-like valley that runs northward from the crater Herodotus: its raised banks, and their irregularities, were easily seen; the internal and external shadows could have been satisfactorily measured had a micrometer been applied. As it was, the much greater breadth of the former showed at a glance that this strange channel was sunk deep below the lunar surface. Taking as a standard the measures given there by Beer and Mædler, he had no doubt that they then saw *without difficulty* spaces of eighty or ninety yards. It is difficult to say *à priori* what should be the minimum visible at the moon in such a telescope. If we assume, as one extreme, the statement of Amici, that the non-coincidence of two black lines on paper can be seen at twenty-eight feet, when it amounts to one-twelfth of an inch, or subtends 51″, then 311 feet should be visible at the moon with 1000. On the other hand, Jurin

states (Smith's Optics) that a piece of silver wire can be seen on white paper, when it subtends 3″, a result depending on the intensity of this metallic reflection. This would give eighteen feet! Dr. Robinson finds that he can see the spider lines of his circle without much contrast of light, when they subtend to him 16″. This gives ninety-seven feet; but it must be remembered that aperture influences visibility as well as magnifying power, though we cannot as yet estimate its effect numerically.

The most important part of their observations were made on nebulæ; and, besides establishing completely the prodigious superiority of this instrument over all yet constructed, they have added some facts to our knowledge of these mysterious objects. A list of them was formed from the invaluable catalogue of Sir John Herschel (Phil. Trans. 1833), comprising such as, from brightness or any other peculiarity, seemed deserving of notice; of which forty were examined by Dr. Robinson and also by Sir James South, except some which the latter lost while making the transit observations required for the meridian line.* They may be separated into three classes; those which are round and of nearly uniform brightness;† those which are round, but appear to have one or more nuclei;‡ and those which are extended in one direction, sometimes so much as to become long stripes or rays.§ Of the first class, all that were examined are easily resolved, even with a triple eye-piece of wide field and power 360, used for finding the objects. In 854 the stars were seen through haze; in 1929 during twilight; and 1833 was noted as "consisting

Sir James South published an interesting and instructive notice of this telescope in the Times, April 16, 1845.

† Nos. 538, 739, 777, 844, 845, 854, 1797, 1833, 1907, 1929.

‡ Nos. 564, 706, 711, 743, 748, 749, 805, 843, 846, 1146, 1385, 1456, 1622, 1881.

§ Nos. 536, 604, 668, 791, 792, 810, 859, 1066, 1132, 1148, 1352, 1357, 1368, 1466, 1926. The numbers and the figures cited in the text are those of Sir John Herschel's catalogue.

of rather coarse stars, and resembling Messier 13." Any increase of brightness towards the centre seemed to proceed from the greater depth of stars there rather than from any notable difference of their magnitude. But the second class presents much more interesting phenomena: the appearances which previous observers had described as *sudden condensation*, *nuclei*, or even single or multiple *central stars*, proving to be clusters of comparatively bright stars, surrounded by much larger collections of minute ones. A very beautiful example of this is 1456, fig. 41, M. 94, described in the catalogue as "very suddenly much brighter, almost up to a nipple-shaped nucleus:" it proved, however, to be "a vast circular cluster of stars, with ragged filaments, in which, and apparently central, is a globular group of much larger stars, power 400." The same system of arrangement (which seems very common) occurs also in 706, 748, 805, and many others: it is also found in the magnificent clusters 1663, M. 3; 1558, M. 53; and 1916, M. 5. In these, the splendour of which is not to be described, besides the stars visible in other instruments (which here seem of the first or second magnitude), the whole field is crowded with others much smaller, to such a degree that, had the first been absent, these would still have been noted as remarkable objects. The interior group is not, however, always central or symmetrical, but has knots of greater condensation, which sometimes (as in 1385) are alone visible in smaller telescopes, and then look like "twin nebulæ;" at others (as in 739), like stars. In 1622, fig. 25, M. 51, which is so well known from a sort of resemblance to Saturn, and from the more exact analogy which, as Sir John Herschel has well remarked, it bears to the Milky Way, we have another different development of this arrangement. Here also the central nebula is a globe of large stars; as indeed had been previously discovered with the three feet telescope: but it is also seen with 560 that the exterior stars, instead of being uniformly distributed as in the preceding instances, are con-

densed into a ring, although many are also spread over its interior. Were the centre absent, we should have a ring nebula;* and were the line of vision near the plane of this ring it would become one of those rays with a bright nucleus and parallel band or satellite nebulæ which occur so frequently in the catalogue. In comparing it with our own sidereal system, Dr. R. thinks we should consider the stars visible to the naked eye, and the larger telescopic classes as constituting the central cluster, while the Milky Way represents the exterior and minuter stars either disposed in an irregular ring or in a stratum, two of whose dimensions are much greater than the third. We have no reason for believing that the comparative brightness of stars depends *only* on their distances; 61 Cygni is not more remote than α Lyræ; much less can we assume that our stars are uniformly distributed: Orion, the Pleiades, Prœsepe, the clusters in Perseus, M. 36 and 37, with many others, are evidently mere knots of condensation in our immediate neighbourhood, our peculiar cluster; and it seems a mere arbitrary assumption to fancy that, were we transported to a remote part of the Milky Way, we should see any thing similar to our present sky.

The nebulæ of the third class which were examined seemed to differ from this type only by being seen obliquely, and therefore projected into ellipses sometimes almost linear. In this last case they proved much more difficult of resolution, probably from greater *optical* condensation, and yielded most easily towards their minor axes. In these the nucleus of brighter stars is sometimes extended like the exterior portion, as in 602, which is of considerable length and easily resolved: the central part has three knots, of which two are represented in fig. 70, all the rest having been invisible. 668 is similar,

It is possible that the exterior part of M 94, may be merely a circular *disc* of stars: the absence of the central globe would make this a planetary nebula: but it is possible that these differ from the annular only in degree; all the latter which he has seen having faint nebulosity within them.

but the central part is of more uniform character. In general, however, the nucleus is globular, and remarkable from the comparative smallness of its diameter, and its very condensed appearance. Either the stars which compose it are few in number, or more closely compacted than is usual. 1132, M. 98, is a good example: "the long ray is resolved, except at the very extremities, with 560; the globular nucleus is seen with 1280 to consist of very close stars." 1148, described as "a nucleus with two branches, a star north following," appeared to Dr. R. as "an irregular ring of stars round a brighter group, but having an appendage like that of M. 51, in which is the bright star seen by H." 1357, fig. 37, is a similar object, both "the ray and appendage being full of stars, but the nucleus requires a higher power to resolve it than the night will bear." In 1466, fig. 84, *the nucleus projects on each side of the ray,* so that its diameter must be greater than the thickness of the exterior stratum.

He could not leave this part of his subject without calling attention to the fact that no REAL nebula seemed to exist among so many of these objects chosen without any bias: all appeared to be clusters of stars, and every additional one which shall be resolved will be an additional argument against the existence of any such. There must always be a very great number of clusters, which from mere distance will be irresolvable in any instrument; and if it prove to be the case that *all* the brighter nebulæ yield to this telescope, it appears unphilosophical not to make universal Sir J. Herschel's proposition, that "a nebula, at least in the generality of cases, is nothing more than a cluster of discrete stars."

These observations will suffice to show how much may be hoped from this telescope; but they are far from being a fair measure of its powers, being made at very low temperatures. Almost always the thermometer was at 22° or 20° when they ceased working; and on one occasion it was as low as 17° the lowest he remembered in Ireland. In such circumstances

it is notorious that even small reflectors act very imperfectly: and he was therefore unprepared for any tolerable action of this gigantic speculum. In the day time it was of course colder than the air, and, if uncovered before that had sunk to its temperature, was covered with dew: when this went off it always defined sharply. The huge mass of metal cooled much more slowly than the atmosphere; and as the difference increased, the performance of the telescope was deteriorated. This arose from no change of figure, as he satisfied himself by throwing the stars out of focus; it was probably the result of currents in the tube occasioned by this difference of temperature. How far it will be possible to obviate this by mechanical means, remains to be tried; but it is certain that the inconvenience does not increase in a higher ratio than the power of the telescope, as he had formerly apprehended. On the same nights, it defined quite as well as the three-feet with a far lower power; and therefore, it is reasonable to expect that it can be used with advantage much more frequently than he once supposed.

Enormous as is its illuminating power, it might be increased one-third, by using it with the front view, supposing it can be properly figured for this oblique action. Without that, he fears that in an instrument where the aperture is so large compared with the focal length, the definition would be imperfect. He verified this by an experiment with the three feet, and found that though the light was increased quite as much as he expected, yet the perfection of the image was utterly destroyed for large stars. There was no exact focus, but merely two places where the sections of the cone of rays were smallest. One, the least exceptionable, shewed a flare in the direction of the slope like a comet's tail: at the other this disappeared, but the star became a sort of curved rectangle with rays from its corners. In the Newtonian form this speculum a few nights before had defined ζ Orionis very well with 500; but now γ Leonis could not be seen

double with any power; the companion of Rigel (some way from the meridian however) was lost in the flare, and even that of Polaris, though perfectly visible, was sadly disfigured by it. It was of course useless to try more difficult tests, as even this degree of imperfection would make it utterly incapable of resolving such objects as the nuclei of the long nebulæ, be its illuminating power what it may. One thing, however, deserves notice, that in consequence of removing the second reflection, the colours of the stars come out with extraordinary splendour.* β Cygni, for instance, had a pureness and brilliancy of yellow, in the large star, which was new to him, though he had seen it in many first-rate telescopes. Lord Rosse does not apprehend any insurmountable difficulty in applying his method to give the form necessary for aplanatic *oblique reflection: more than one plan for this has occurred* to him; and Dr. R. believes it is his purpose, as soon as the six-feet has its machinery completed, to try them on one of the three-feet specula, and, if successful, to alter the great one.

As it is, Dr. R. congratulates the Academy and their country on the success of this matchless instrument; to which, as nothing at all approaching to its power has yet existed, so it is not probable that there will soon be any superior. It has been reported that the French Government, at the suggestion of M. Arago, are about to construct an achromatic of a metre aperture. Supposing homogeneous discs of glass can be obtained and wrought of that magnitude, there remain other difficulties. The optician who proposed to supply them stated that they would weigh at least four hundred pounds; now these, when mounted, must be supported by at most two lateral bearings; and it is known that a very moderate pressure produces in

* The lenses of achromatics have often a tinge of green or straw colour which modify the colour of objects seen through them. Something of this may perhaps cause the predominance of green and "cinereus" which exists in the Dorpat catalogue.

glass a double refraction, most injurious to its performance in an object glass. But supposing this and the equally probable change of curvature from the weight of the lenses obviated, still such an achromatic would be far below the six-feet in quantity of light. From Amici's experiment with an object glass of two and a half inches it follows that it equals a Newtonian when their acting surfaces are as six to ten: this would imply in the great one an aperture of fifty-six inches and a focal length of eighty feet. But the absorption certainly increases with the thickness of the medium, though neither the law of this, nor the loss by the reflections at the four surfaces, are accurately known. Mr. Potter found that a good object glass by Dollond of four inches aperture and six feet focus transmitted but 0.66 of the incident rays. This gives the ratio of the equivalent surfaces 0.74, and it will be still greater where the glass is three or four inches thick. It is said that the construction of a reflector still larger than this is contemplated by a northern Sovereign who has already shewn himself a most munificent patron of Astronomy. If so, none will rejoice more than Lord Rosse himself. It was not the mean desire of possessing what no other possessed, or seeing what no other had seen, that induced him to bestow so many precious years on this pursuit: had such been his motives, he would have kept to himself his methods, instead of opening his workshops without reserve to all who had the slightest desire of following his steps, and communicating in the most liberal manner the fruits of long and painful experience. His sole object is to extend the domain of astronomical knowledge: and the more common such instruments become, the more perfectly will it be fulfilled.